A Linear Waveguide Transverse Slot Array with Parasitic Dipole Layer and Reflection Canceling Posts for Grating Lobes Suppression

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I. Introduction

A broad-wall transverse slot array is important in that it radiates linear polarization orthogonal to that of shunt slot array. A bore-sight beam transverse slot array requires the slot spacing of a guided wavelength λg, which is always greater than the free space wavelength λo, hence the array suffers from unwanted grating beam radiations. From the design point of view, it utilizes non-resonant slots and array design taking the reflection from elements into account becomes a kind of large EM analysis which is computationally heavy. The array input reflection is also large as each slot unit, spaced at a guided wavelength λg, adds up the reflection in phase at the input. A few methods have been proposed to deal with the problem of the grating lobes of transverse slots. A baffle technique was proposed by Josefsson [1], where radiation takes place between two parallel plates to eliminate the grating lobes. A partially dielectric filled waveguide was introduced by Joubert [2] to reduce the slot spacing to less than λo. The authors proposed a new way of grating lobe suppression by installing a parasitic dipole layer over the slot array without considering the interior reflection problem of the waveguide into account [3-4]. The input reflection problem from a slot was studied by Park et al. [5], where the reflection is controlled with an inductive post. Recently the authors introduced a unit element [6] consisting of a transverse slot, a post and a pair of parasitic dipoles for an application in the bore-sight beam antenna array with suppressed grating lobes and minimized reflections. The pair dipoles are placed at a height of half free space wavelength λo/2 from the slot to generate a Dual Parasitic Beam (DPB) [4] that suppresses the radiation of the slot in the directions of the grating lobes. The post position for each unit is designed to minimize the reflection.

In this paper, the authors have presented a design of transverse slot array with the element mentioned above. The design parameters for a unit radiator consisting of a single slot, an inductive post and a pair of parasitic dipoles are determined for specified excitation coefficients by the Method of Moments (MoM) analysis. A 5-element transverse slot array with uniform excitation is constructed by simply cascading units thus designed without considering mutual coupling. This is acceptable since units are largely spaced at a guided wavelength λg and reflection free. The array performance is simulated by the Ansoft HFSS. The simulated results show that input reflection of the array is less than -15 dB over 100 MHz in 11.9 GHz band while the grating beam can be suppressed by more than 15 dB at same frequency band.

II. Unit Analysis Model

The structure of the array unit consisting of a slot, a post, and pair dipoles is shown in Fig. 1(a). The layout of the structure is shown in Fig. 1(b). All elements of the unit are electromagnetically coupled. The coupling EM integral equations in term of excitation coefficients on the slot, post and dipoles are obtained by applying the continuity conditions of the magnetic fields on the slot apertures and null conditions of the electric fields on the post and dipoles. The integral equations are solved by using the Gelarkin's MoM. Radiation patterns are calculated from the excitation coefficients [7-8].

III. Unit Element Analysis and Array Design

The initial design parameters of the array have been obtained at 11.9 GHz in the MoM analysis of the array unit, as shown in Fig. 1, consisting of a slot, a post and a dipole pair. The slot is considered narrow of width 1 mm and cut on the broad wall of WR-120 waveguide. The dipole dimensions are

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designed based on the maximum radiation suppression in the grating beam direction. The dipole width is 2 mm and length is 11.8 mm. The dipoles are placed at an x-offset of 6.5 mm and a height of a half free-space wavelength λo/2 to generate the Dual Parasitic Beam (DPB) [4]. The post diameter is 2 mm. The slot dimensions and phase progression of each unit can be obtained from the design curves in Fig. 2 while the positions for the inductive-posts can be obtained from the design curves in Fig. 3. All the unit design curves are obtained by setting a design goal at minimized unit reflections (less than -40 dB) so that each unit in the array can be excited almost with a traveling wave. A small 1D array is formed by cascading 5 radiating elements to demonstrate the improved reflection characteristics and grating lobe suppression of the transverse slot array. The layout of the array is shown in Fig. 4. In the array the dimensions and positions for slots, posts and dipoles are decided such that all radiating units have uniform coupling and phase to obtain a bore-sight beam. As indicated in Fig. 2 that each unit in the array radiates a certain percentage of input power so that each unit has uniform illumination. The reflection and radiation characteristics of the full array are simulated by the HFSS. The frequency dependence of the input reflection of the array is plotted in Fig. 5, which shows that the reflection remains below -15 dB over 100 MHz bandwidth. The normalized radiation patterns are shown in Fig. 6 at 11.9 GHz, where four different plots, space factor in dotted line, unit pattern in dashed line, array pattern without external coupling in line with crosses, and array pattern with external coupling in solid line, are presented. The array pattern without coupling is obtained from the multiplication of the space factor and unit element pattern of the array. The comparison between array patterns suggests that the external mutual coupling effect between units is not so strong, as unit spacing is large. However the grating suppression is more that 15 dB in both cases.

IV. Conclusion

A transverse slot array is designed by introducing the uncoupled unit radiating elements consisting of a transverse slot, a post and pair parasitic dipoles to minimize input reflection as well as to suppress array grating lobes. The inductive post controls each slot reflection while the parasitic dipoles control each unit radiation in the grating beam direction without disturbing the bore-sight beam. Simulation results show that the array has input reflection below -15 dB over a 100 MHz bandwidth while the pattern suppression is 15 dB in the grating beam direction. The fabrication of the array is now underway.

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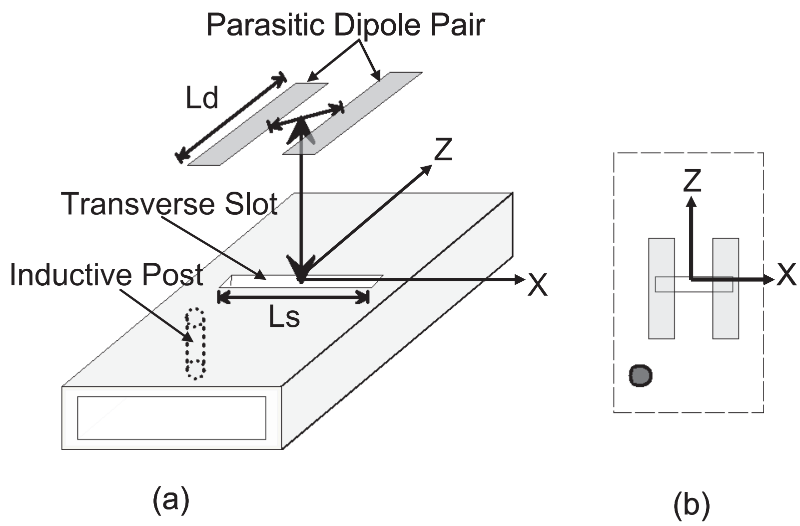

Fig.1 (a) The structure of the grating lobes suppressing unit of a waveguide transverse slot, with a post and a dipole pair, (b) layout of the unit.

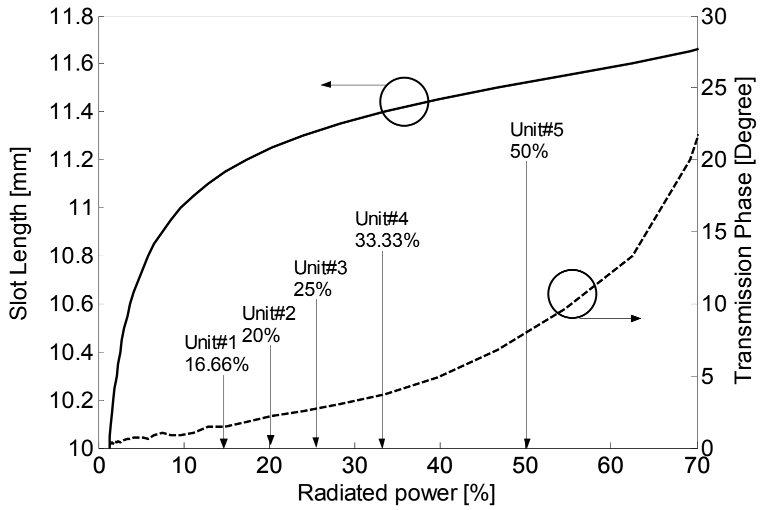

Fig. 2 Slot lengths and unit phase progression for specified level of radiation power.

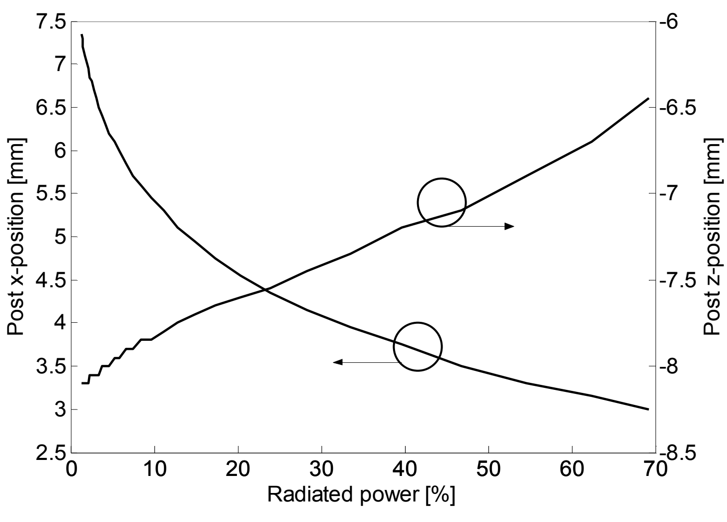

Fig. 3 Positions for the inductive posts for specified level of radiation power.

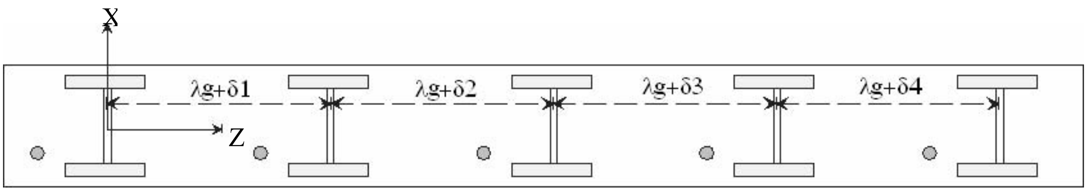

Fig. 4 Layout of the 5 unit transverse slot array with the unit the spacing λg+δn, where λg=1.32λo and δn is the phase progression error between adjacent units.

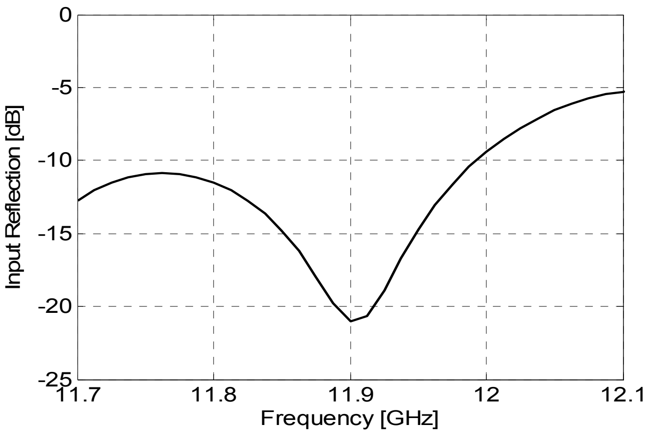

Fig. 5 Frequency dependence of the input reflection of the 5 unit transverse slot array.

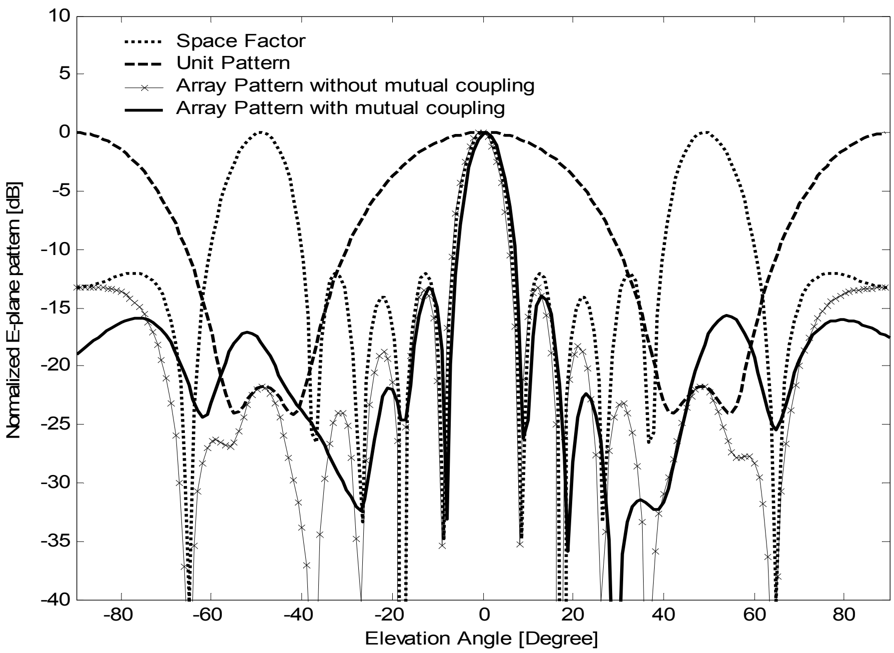

Fig. 6 Normalized pattern of the 5 unit transverse slot array.